

State of California  
The Resources Agency  
Department of Water Resources  
Division of Flood Management

**THE HYDROLOGY OF THE 1987-1992 CALIFORNIA DROUGHT**

Technical Information Paper

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October 1992

## THE HYDROLOGY OF THE 1987 - 1992 CALIFORNIA DROUGHT

This paper summarizes the hydrologic facts of the 1987-1992 California drought, which continues in Northern California. The six year shortfall in rain and snow has resulted in runoff about half average, causing major shortages in water supply for most California users. Reservoir storage this fall, although more than in the fall of 1977 after that severe two-year drought, is 56 percent of average which is 5 percent less than last year and the lowest during the current drought. Carryover surface storage for next year is minimal. Therefore, now more than ever, California's welfare depends on a generous 1992-93 rainy season.

### Climate Factors

California is situated near the southern margin of the prevailing westerly wind belt, a region on the globe between 30 and 60 degrees north latitude where a continuing series of cyclonic storms progress from west to east producing periodic rainfall. To the south is a zone of semi-permanent high pressure areas with descending warm, dry air. The high pressure area which affects California is known as the Pacific High. The global zones of weather shift with the season. Much of the year California is in the high pressure belt which accounts for the fair weather and lack of precipitation during the summer. During the winter season, the storm belt shifts southward to occasionally place the state under the influence of Pacific storms to bring vitally needed rain and snow.

Most of California's moisture originates in the Pacific Ocean to the west and southwest. Storms with a long southwesterly fetch generally produce more precipitation (sometimes floods) because these storms tap air with higher moisture content originating over warmer water. As moisture laden air is blown over mountain

barriers, such as the Sierra Nevada, the air is lifted and drops additional rain or snow in the high country normally on the westerly slopes. The mountain induced precipitation is called orographic precipitation and is very important to water supply. For example, the one-mile high Blue Canyon weather station located northeast of Sacramento averages 63 inches of precipitation a year, about 3-1/2 times the 18 inches expected at Sacramento in the middle of the Central Valley.

The direction of orographic wind flow is important. The greatest amount of water is wrung out when wind flow is at right angles to the mountain barrier or from the southwest for the Sierra Nevada. A more southerly direction, such as occurred frequently during water year 1992, is not as productive.

Normally during the wet season, 5 to 7 major winter storms occur which drop 1 to 2 inches of rain in the Sacramento Valley and corresponding equivalents of rain and snow in the Sierra. A shortfall of a couple of major storms causes a dry year; conversely a couple of extra storms produce a wet runoff year. An unusually persistent Pacific High over California during the three mid-winter wet months (December through February) predisposes the year toward the dry side.

There are a multitude of factors which can influence Northern California weather, some in ways which are not understood. El Niño, the warming of the ocean in the eastern tropical Pacific, does have influences around the world. There seems to be a relationship between El Niño and wetter conditions in the southwestern states of Arizona and New Mexico (and for Southern California) and a tendency for the Pacific Northwest to be warm and dry. Conditions during water year 1991-92 generally followed a pattern expected during an El Niño event. But no clear signal for Northern California is evident from the record. Some El Niño years are wet; others are dry. The El Niño conditions evident a year ago in the Pacific Ocean have disappeared,

except for some leftover warmth offshore from California, which is expected to gradually fade out this coming winter.

### Precipitation During the 1987-92 Drought

Statewide precipitation for each water year has been below average since 1986. Statewide and Northern Sierra percentages are listed on Table 1. Water year 1992 (which extended from October 1, 1991, through September 30, 1992), produced well above average precipitation across the southern third of California, as shown on Chart 1. But amounts were light across the northern third of the State and especially in the Sierra Nevada. As a result, the statewide precipitation average was 86 percent and the runoff even lower at 43 percent of average. In 1989, when Sacramento basin runoff (Table 2) was about 3/4 of average, northern basins were near normal and the southern portion of the state was dry. Water year 1977, which was the driest year of record, is also shown on Tables 1 and 2.

Table 1  
Percentage of Average Precipitation

	<u>Water Year</u>						
	<u>1977</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>
Statewide	45	61	82	86	69	76	86
Northern Sierra	38	57	70	101	72	65	72

Chart 2 shows the historical water year record of northern Sierra precipitation. Bar Charts 3 and 4 provide the complete history of rainfall at two long term stations, Nevada City in the north and Santa Barbara in the south. Note the increased rainfall during the last two years at Santa Barbara.

Table 2

Percentage of Average Runoff

	<u>Water Year</u>						
	<u>1977</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>
Statewide	20	48	48	72	45	43	43
Sacramento River Index	28	50	50	80	50	46	48
Sacramento River Index (MAF)	5.1	9.2	9.2	14.8	9.2	8.4	8.9

Each drought is different. The current drought for the Sacramento River basin is unique in that runoff in 5 of the years has been very similar, about half of average. Only in 1989 was there a substantial change. The Sacramento River Index (the sum of unimpaired runoff of the four major rivers in the basin) is also shown on Chart 5.

Precipitation during the 6-year 1987-92 period was about 3/4 of average. The deficit in precipitation was magnified in runoff which was about half of average over the 6 year period. A portion of each rainy season's precipitation goes into wetting the ground before runoff can begin. Therefore, the impact of a shortfall in precipitation is amplified in runoff deficits. Likewise, early and late season rainfall is not as effective in producing runoff because a larger fraction of the moisture is used by vegetation.

Reservoir Storage

California's reservoir storage proved its worth during this drought, especially during the first three years. By 1990, however, reserves were largely depleted and major curtailments in water delivery became necessary. Chart 6 presents October 1

storage in the 155 major reservoirs within California. Chart 7 shows the same data for six reservoirs in the Central Coast hydrologic area. The improvement due to the greater Southern California precipitation amounts this past year is evident. (See also the chart on Santa Barbara precipitation.) Chart 8 provides similar information for the major reservoirs of the federal Central Valley Project and the State Water Project.

Statewide carryover storage in the 155 major reservoirs on October 1 was about 1.1 million acre-feet or 5 percent less than a year ago. This is the lowest of the current 6-year drought, but still nearly 5 MAF over the extremely low 1977 storage amount. Combined CVP and SWP carryover was about 0.3 MAF less than a year ago.

Table 3  
Reservoir Storage on September 30

	<u>1977</u>	<u>1986</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>
	<u>In Million Acre-Feet</u>							
155 Major Reservoirs	7.78	26.75	18.92	14.83	16.72	13.57	13.78	12.67
6 Major CVP	1.31	8.43	6.27	4.60	5.10	3.98	3.29	3.11
6 Major SWP	1.46	4.25	3.01	2.47	2.88	1.87	2.43	2.30
	<u>In Percent of Historical Average</u>							
155 Major In-State	35	119	84	66	74	60	61	56
6 Major CVP	18	113	84	62	68	53	44	42
6 Major SWP	41	120	85	70	81	53	69	65

Because of federal and state Endangered Species Acts, including temperature problems for salmon, it is not likely that storage levels in the CVP and SWP system could be drawn as low as in 1977, so probably half the 5 MAF of statewide storage in

excess of 1977 amounts would not be usable in 1993 if the year is dry. To place these storage amounts in perspective, total normal net water use in California is about 34 MAF. About 5 MAF more is needed, on the average, for required Sacramento-San Joaquin Delta outflow. So it is quite evident that most of next year's supply must be generated from the next season's runoff, with little more to be drawn from surface reservoir storage.

### Comparison with Past Droughts

Average Sacramento River Index runoff during the 1987-92 six-year period was about 10.0 MAF, or 54 percent of the average 18.4 MAF of runoff. While unusual, this is not the driest of record. Runoff during the historical 6-year critical dry period from 1929 through 1934 was 1 percent less at about 9.8 MAF. (See Chart 9). However, on the San Joaquin River system, the current drought exceeds, by a large margin, the historical 1929-34 runoff. (See Chart 10). Because 1932 was above average in the southern Sierra, the earlier drought was eased somewhat in that region.

Long droughts in excess of 3 years seem to be rare in Northern California. Except for the 1929-34 period, there is no evidence of previous droughts exceeding 3-years in length from the historical runoff record (see Chart 11 for the Sacramento River Index since 1906) or in the historical precipitation record which goes back to 1850 for a few early stations and is reasonably complete from the early 1870s when the major railroads were built. Long droughts in Southern California are more common.

The estimated recurrence frequency for a 6-year period like 1987-92 for the Sacramento River Index is 1.4 percent, or about once in 70 years, based on the

1906-92 record. On the San Joaquin River, where the current drought has been more severe, the estimated recurrence frequency is only about 0.3 percent, approximately a 1 in 300 year event. These statistics represent both length (6 years) and severity of drought. The following table presents estimated risk frequency of the current drought series in the two basins.

Table 4  
Drought Frequency Probabilities

<u>Water Year</u>	<u>Length, years</u>	<u>Risk of Occurrence, Percent</u>	
		<u>Sacramento</u>	<u>San Joaquin</u>
1987	1	11	6
1987-88	2	5	2.4
1987-89	3	8	2.5
1987-90	4	4	0.8
1987-91	5	2.5	0.6
1987-92	6	1.4	0.3

It is not wise to place much trust in statistics for extreme events because the record is only about 90 years. Some long term climate reconstruction studies show periods in the past which are different than the last 90 years.

In order to get an idea of what the longer record looks like, indirect indicators of runoff are needed. The most promising tool for looking year by year into the past is by use of tree ring data. With the right selection of trees, the thickness of annual growth rings indicates the wetness of the season. Tree ring widths are not a perfect match (they did not reproduce the 1976-77 drought) but have been useful to investigate how the measured runoff or precipitation record compares with a longer sweep of history.

A 420 year reconstruction of Sacramento River runoff from tree ring studies was made for the Department of Water Resources in 1986 by the Laboratory for Tree-Ring Research at the University of Arizona. (The Sacramento River study is described on page 28 of DWR Bulletin 160-87.) This reconstruction showed that the 1928-34 drought was the worst in the reconstructed record which began with year 1560. Table 5 provides a listing of multi-year droughts from the reconstruction. These are runs of consecutive years under 15.7 MAF, the historic median runoff. The table shows multi-year droughts three years or more in length from the tree ring study prior to 1900 and the measured record of similar events since 1900.

Since the tree-ring reconstruction doesn't always match the measured record where there is overlap, the weight that should be given to the Table 5 information is not clear. What is apparent, is that few droughts prior to 1900 exceeded three years and none have lasted over 6 years, although there was an eight-year period of less than average runoff from 1839 through 1846.

John Bidwell, an early pioneer who arrived in California in 1841, confirmed that 1841, 1843 and 1844 were extremely dry years in the Sacramento area.

Table 5  
Sacramento River Multi-Year Droughts

Reconstructed from Tree-Rings Prior to Year 1900

Period	Length (years)	Average Runoff (MAF)
1579-82	4	12.4
1593-95	3	9.3
1618-20	3	13.2
1651-55	5	12.3
1719-24	6	12.6
1735-37	3	12.2
1755-61	6	13.3
1776-78	3	12.1
1793-95	3	10.7
1839-41	3	12.9
1843-46	4	12.3
1918-20 (actual)	3	12.0
1929-34 (actual)	6	9.8
1959-62 (actual)	4	13.0
1987-92 (actual)	6	10.0

#### Outlook for Water Year 1993

In essence, the 1993 water supply will be composed of two factors; carryover storage from water year 1992, which is known and the amount of precipitation and runoff this coming rainy season, which is unknown. Carryover reserves this year are minimal. The safest assumption is that future weather will be statistically like the historical record. Conventional procedures assume that precipitation next season is equally likely to be like that of any of the past years of record. However, there is a

small influence on stream base flow because the watersheds are dry from drought in previous years and this September was very dry. This may reduce runoff in the Sacramento Basin about 6 to 9 percent from levels otherwise to be expected. Normal and estimated 1993 runoff probabilities are shown on Chart 12.

October is not an important rain month, accounting for about 6 percent of the annual precipitation in the Sierra. November through March account for about 3/4 of the yearly precipitation.

Research into long range (3 months or more) weather forecasts is being encouraged and, at times, some skill has been observed in winter and spring forecasts. For now, long-range weather forecasting is not reliable enough to be a usable tool for water managers except in instances where backup supplies are available when the forecast fails. The National Weather Service Climate Analysis Center routinely issues a 30 and 90-day outlook each month. The most recent 90-day outlook from September 29, 1992, projects northern California to likely be drier than normal with near normal precipitation in the extreme southern end of the state (Chart 13).

Although October precipitation is not a good predictor of winter season precipitation, warm fall temperature does seem to be linked to winter season rainfall. There is a tendency for warm falls to be followed by less than average winter precipitation in Northern California. So far, this fall has been well above average in temperature, although not as much as last year.

Based on historical statistics, with an allowance for dry watersheds, the most likely 1993 Sacramento River Index would be about 80 percent of average water year runoff or in the 14 to 15 MAF range. A dry fall will reduce the outlook substantially by early December, when the initial forecast of Sacramento River runoff is prepared.

Last year, for example, Northern Sierra precipitation during October and November was 62 percent of average. The December 1 median forecast reflected the dry fall and was only 12.7 MAF, 69 percent of average. The actual runoff turned out to be even less at 8.9 MAF. Hopefully, 1993 will be better.

## List of Charts

Chart 1, Water Year 1992 Precipitation

Chart 2, Northern Sierra Precipitation

Chart 3, Nevada City Precipitation

Chart 4, Santa Barbara Precipitation

Chart 5, Sacramento River Index

Chart 6, Storage in 155 Major In-State Reservoirs

Chart 7, Storage in 6 Major Central Coast Reservoirs

Chart 8, October 1 Reservoir Storage, CVP and SWP

Chart 9, Comparison of Droughts - Sacramento River

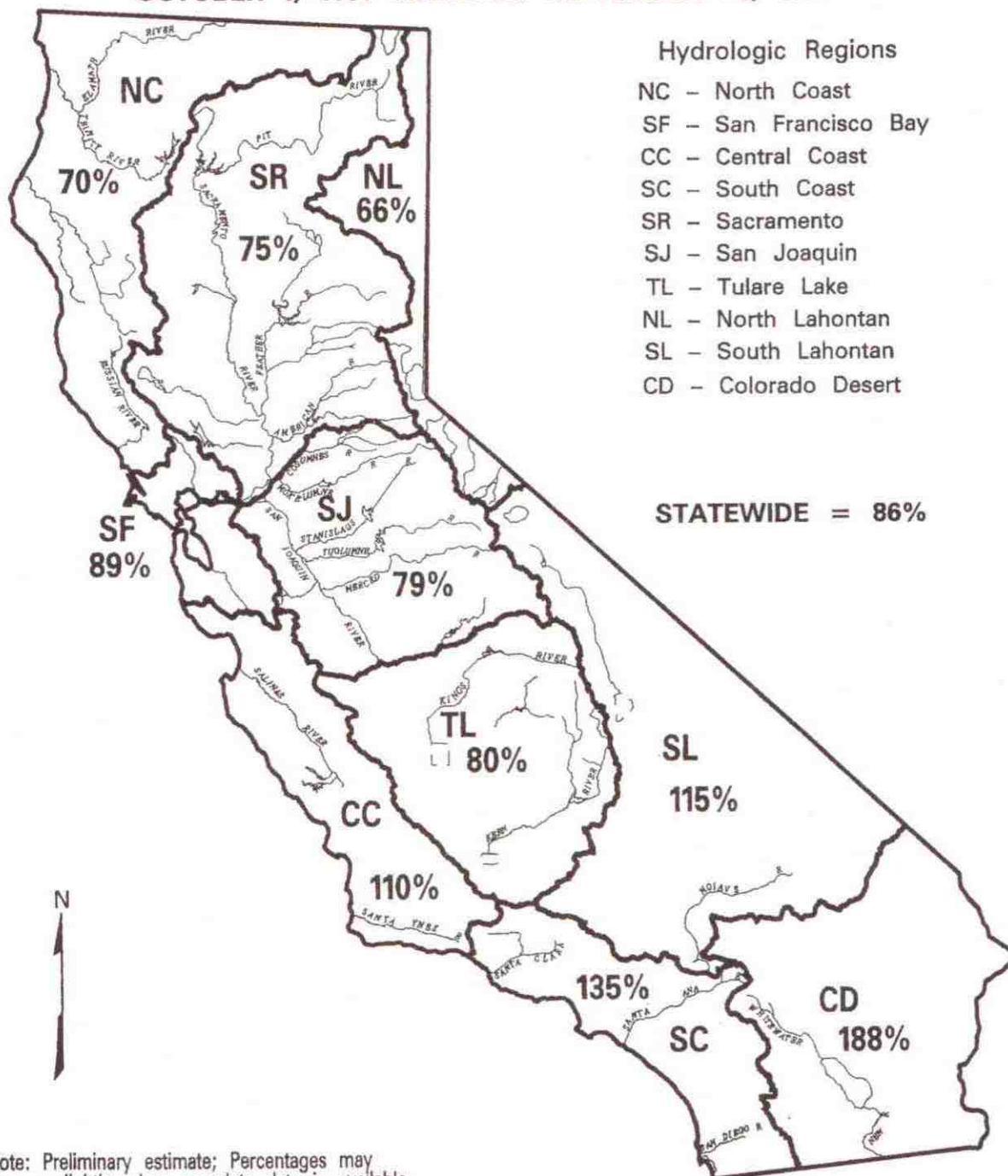
Chart 10, Comparison of Droughts - San Joaquin River

Chart 11, Sacramento River Index Since 1906

Chart 12, Water Year Runoff Probabilities, Sacramento River Index

Chart 13, NWS Precipitation Forecast, October through December

**WATER YEAR 1992 PRECIPITATION**  
**IN PERCENT OF AVERAGE**  
**OCTOBER 1, 1991 THROUGH SEPTEMBER 30, 1992**



# NORTHERN SIERRA PRECIPITATION

## 8 STATION AVERAGE

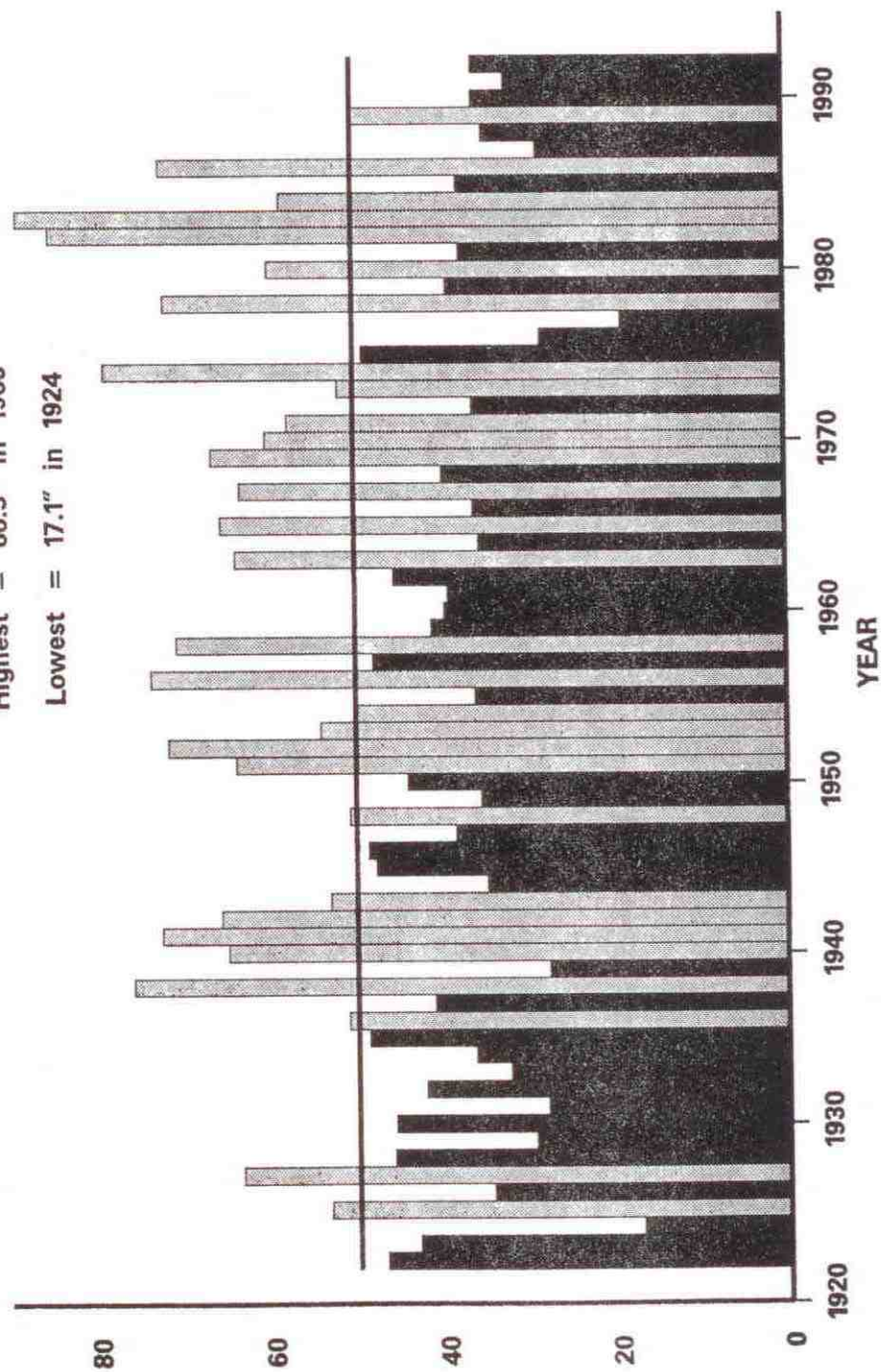
(Inches)

1922 - 1992

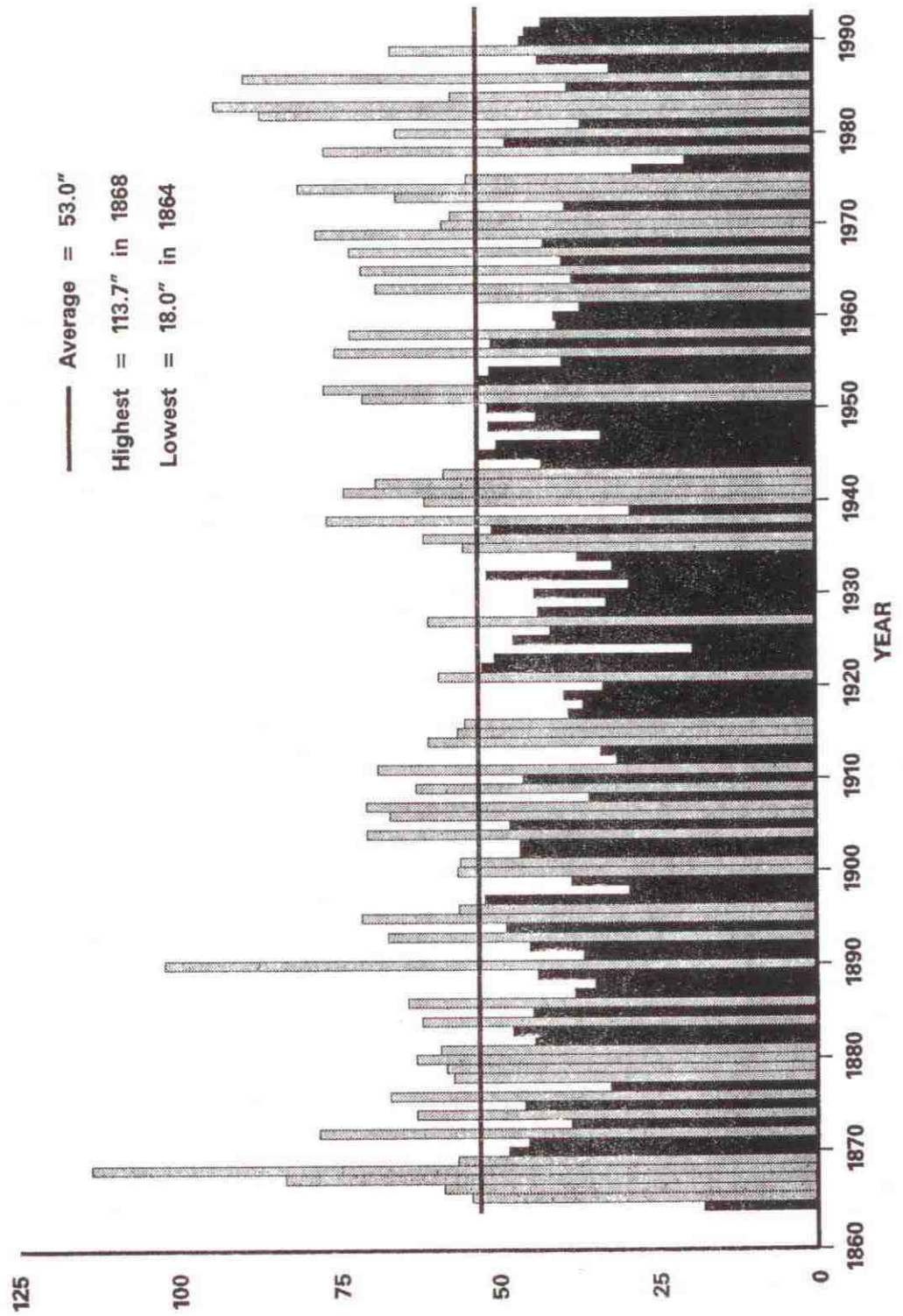
— Average = 49.8"

Highest = 88.5" in 1983

Lowest = 17.1" in 1924



# NEVADA CITY WATER YEAR PRECIPITATION (Inches) 1864 - 1992

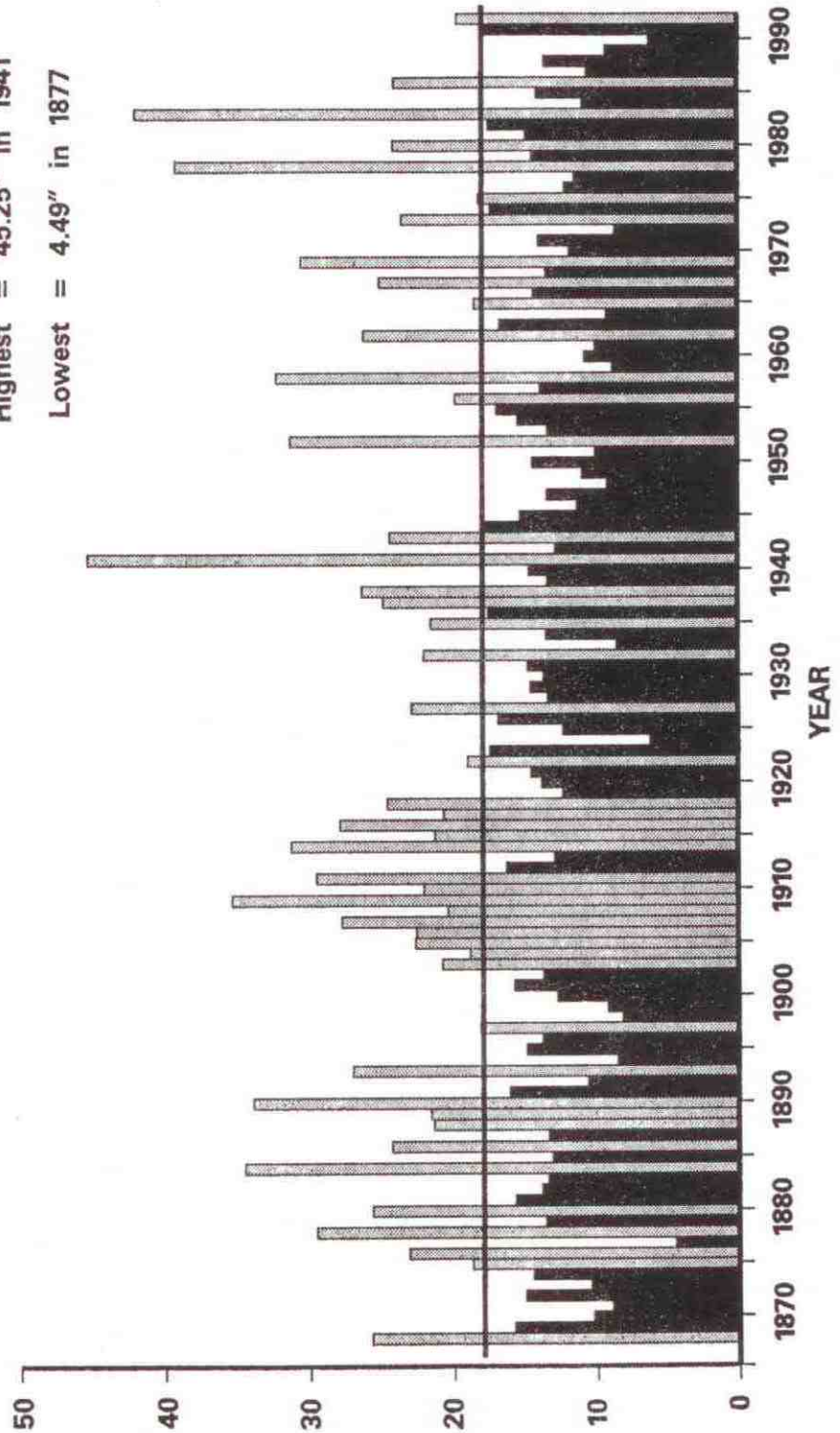


# **SANTA BARBARA** **WATER YEAR PRECIPITATION** (Inches) 1868 - 1992

Average = 17.9"

Highest = 45.25" in 1941

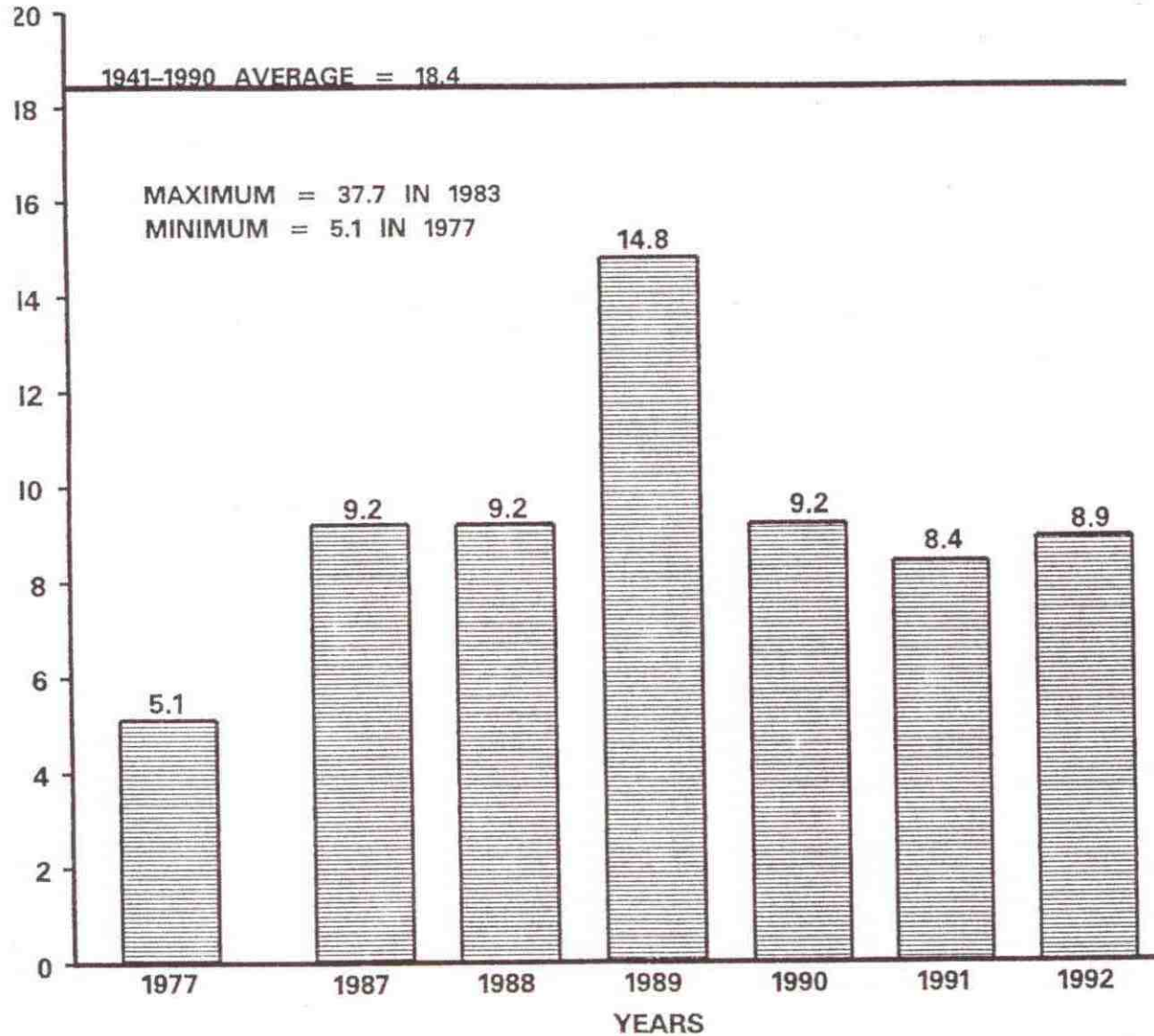
Lowest = 4.49" in 1877



# SACRAMENTO RIVER INDEX

MILLION ACRE FEET

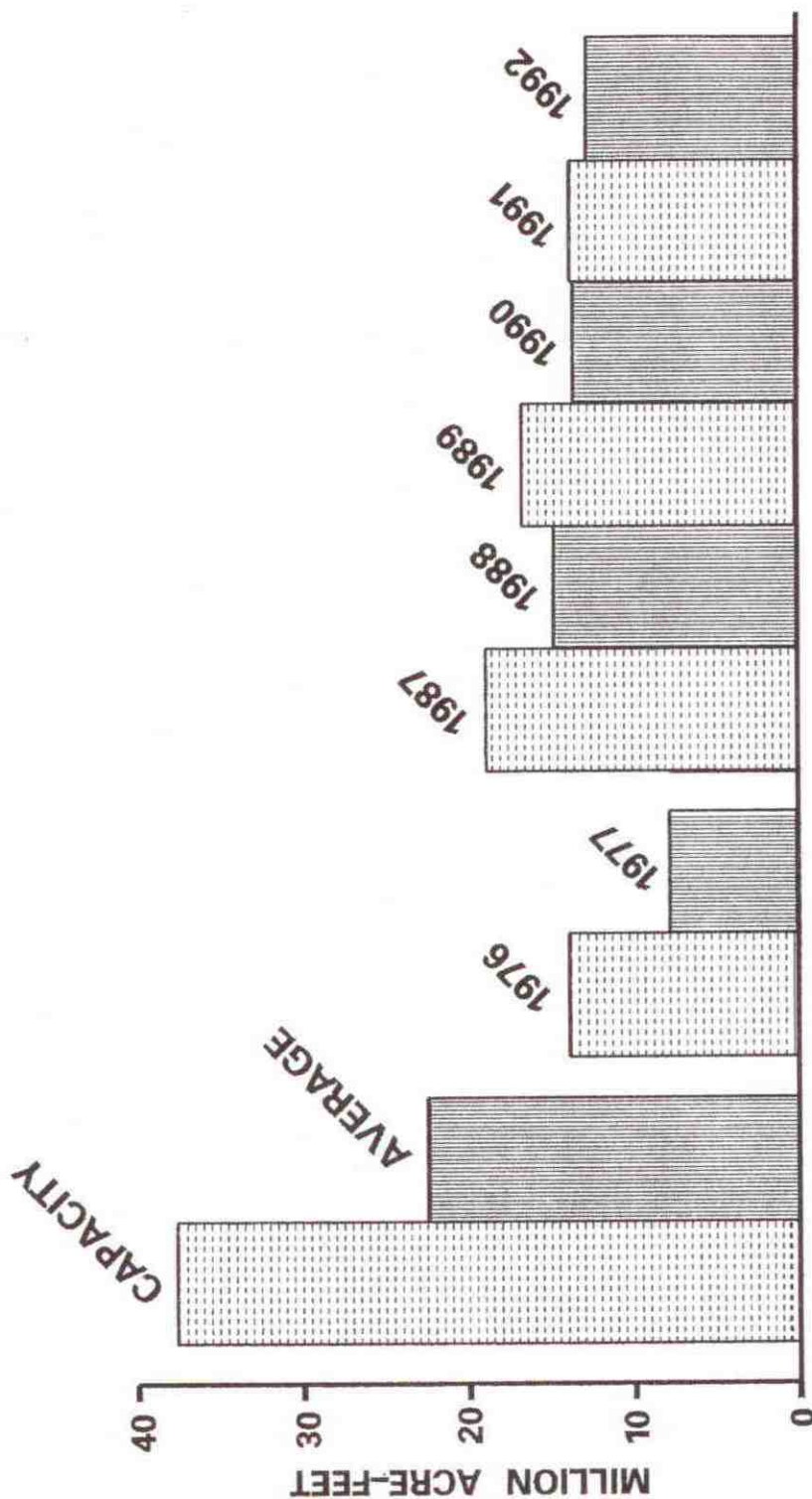
(Water year October 1 through September 30)



NOTE: The Sacramento River Index is the sum of unimpaired runoff from the Sacramento River at Bend Bridge, Feather River inflow to Oroville, Yuba River at Smartville and American River Inflow to Folsom.

# STORAGE IN 155 MAJOR IN-STATE RESERVOIRS

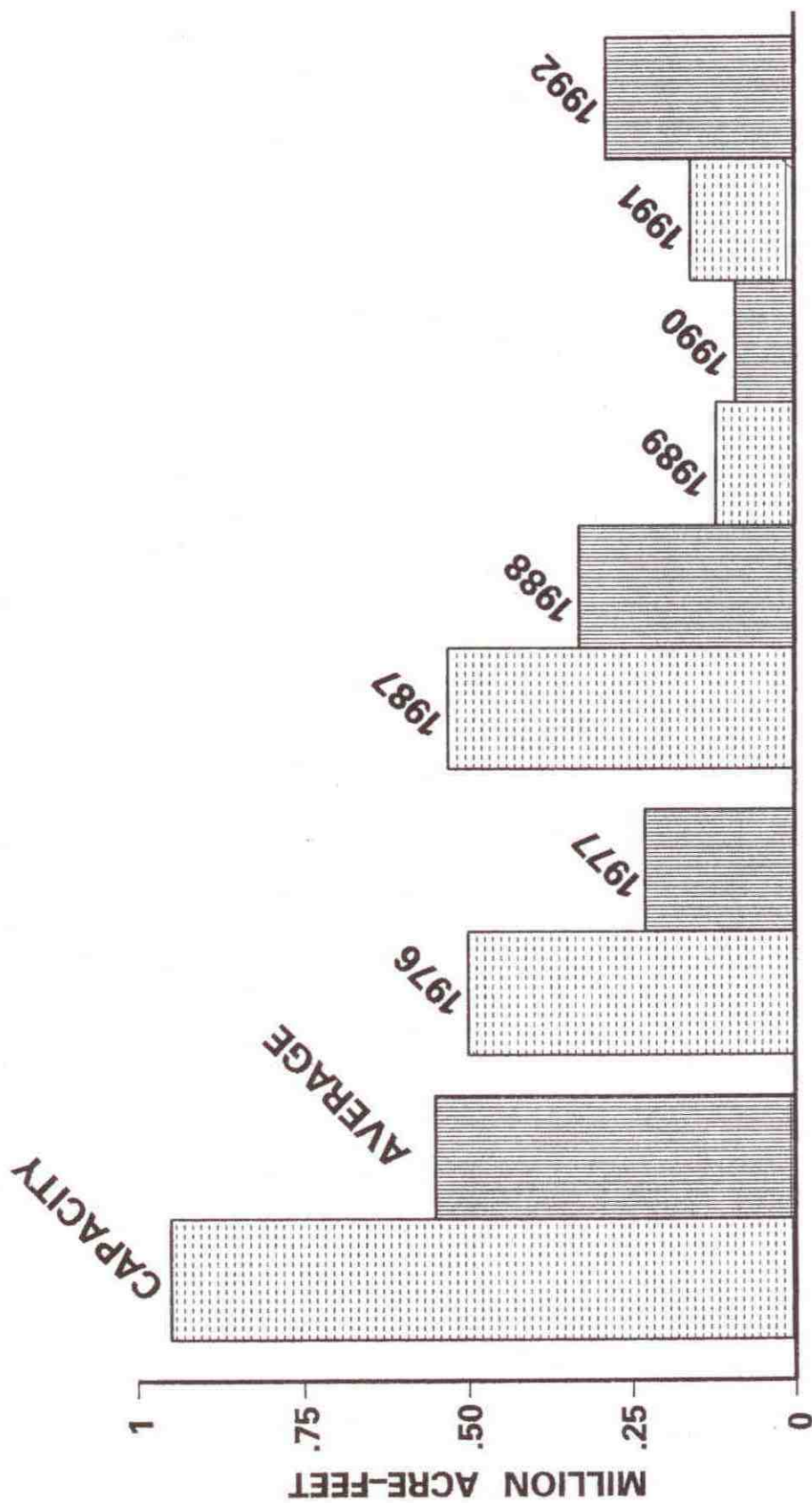
October 1



NOTE: The 1987 - 1992 storage amounts include New Melones and Warm Springs Reservoirs which began operation after 1977.  
 1989 - 1992 storage amounts also include the new Spicer Meadows Reservoir on the Stanislaus River.

# STORAGE IN 6 MAJOR CENTRAL COAST RESERVOIRS

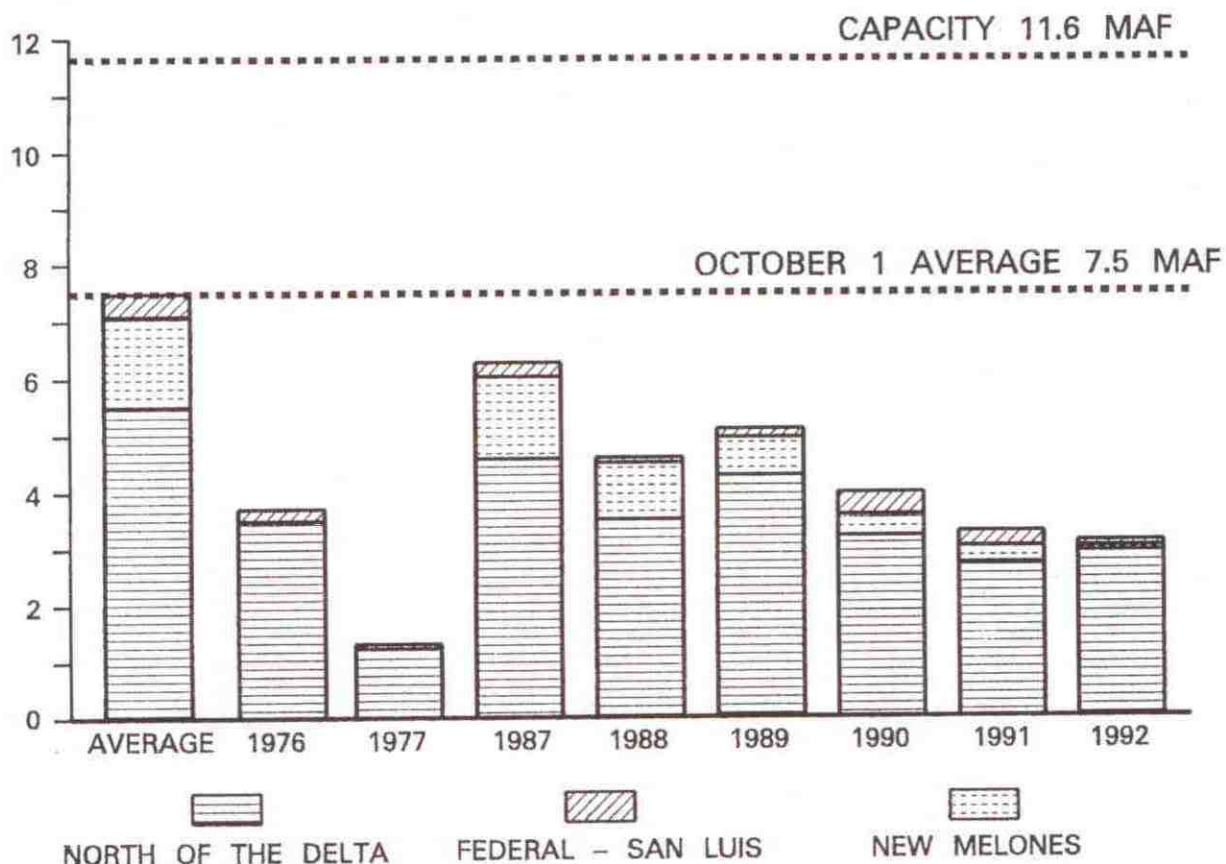
OCTOBER 1



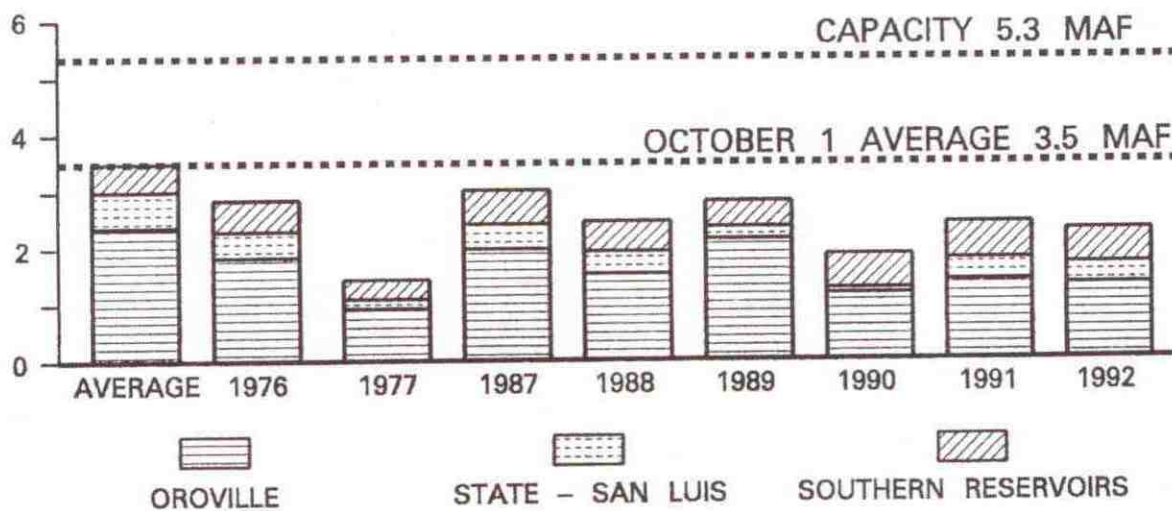
# OCTOBER 1 RESERVOIR STORAGE

MILLION ACRE-FEET

## CENTRAL VALLEY PROJECT



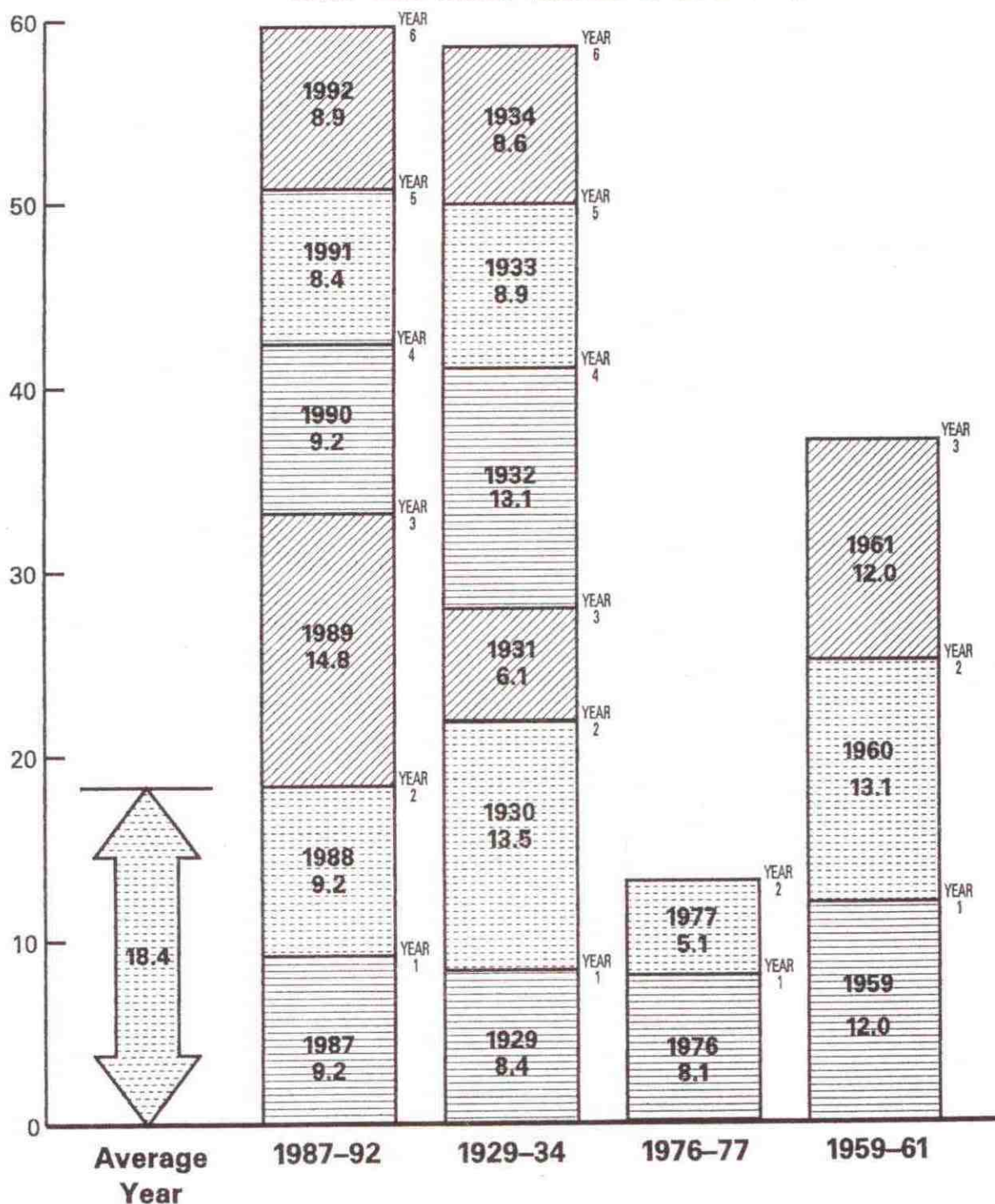
## STATE WATER PROJECT



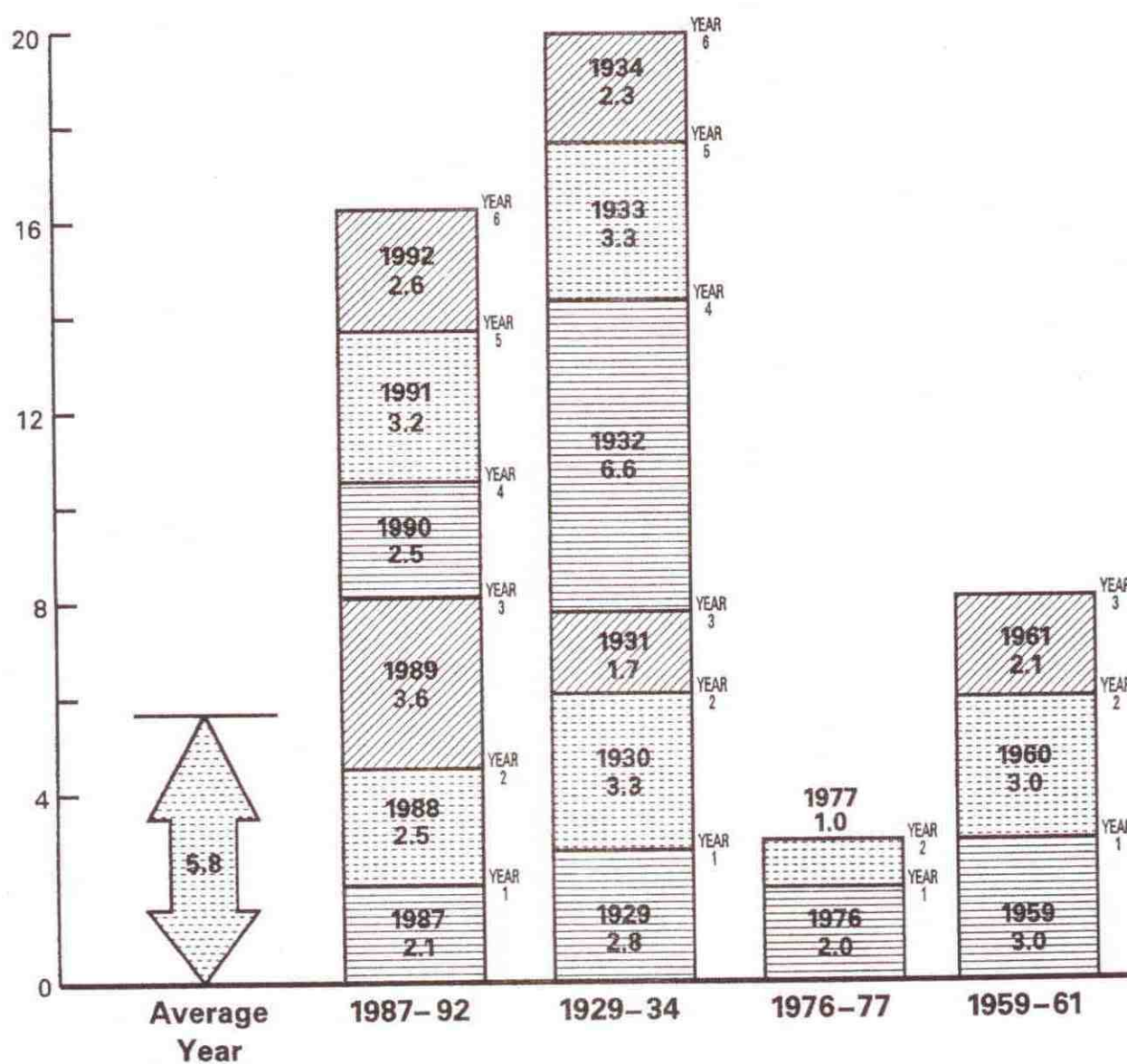
# COMPARISON OF DROUGHTS

## Sacramento River Index

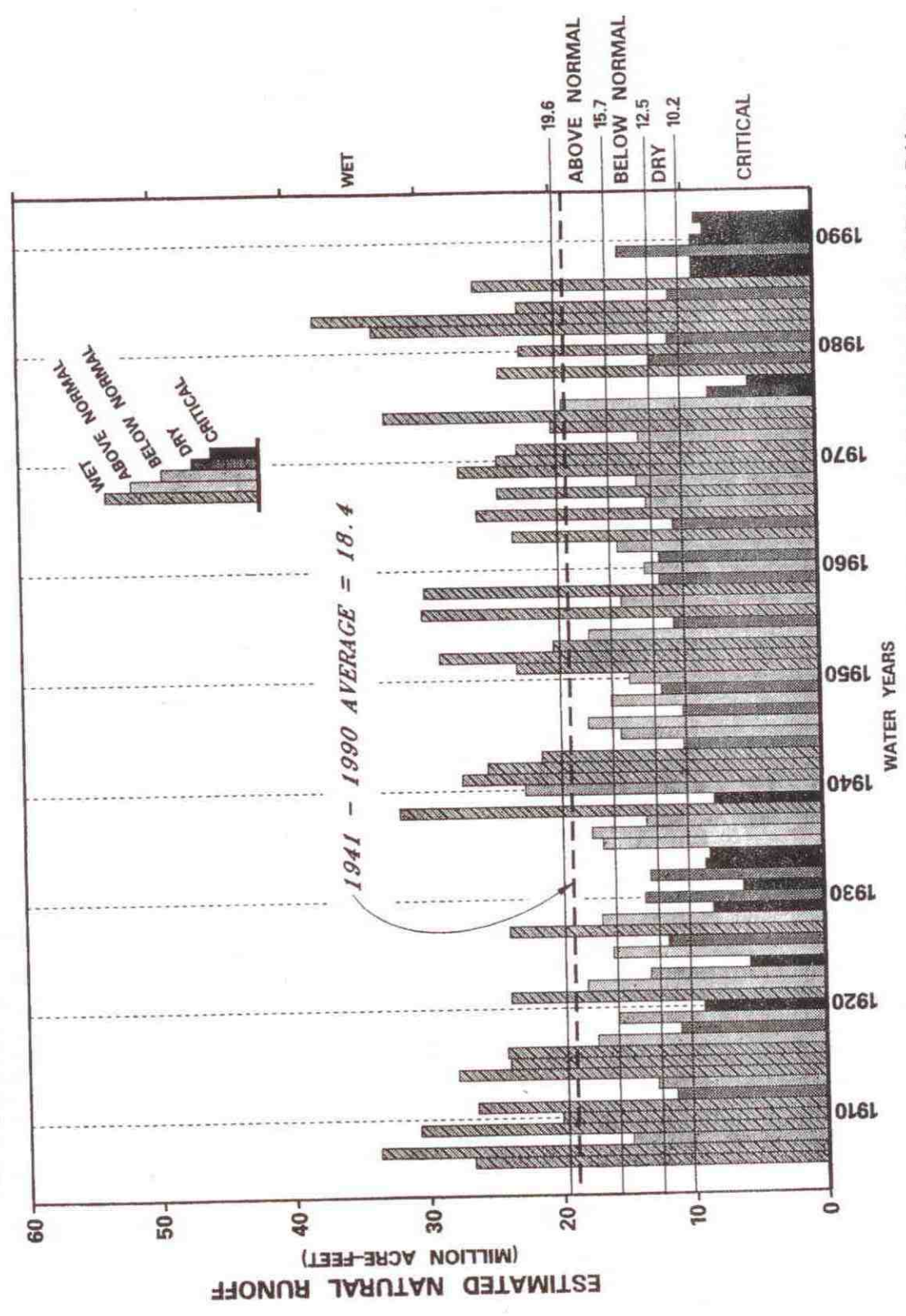
Water Year Runoff (millions of Acre Feet)



**COMPARISON OF DROUGHTS**  
**San Joaquin River Index**  
Water Year Runoff (millions of Acre Feet)



# SACRAMENTO RIVER INDEX SINCE 1906

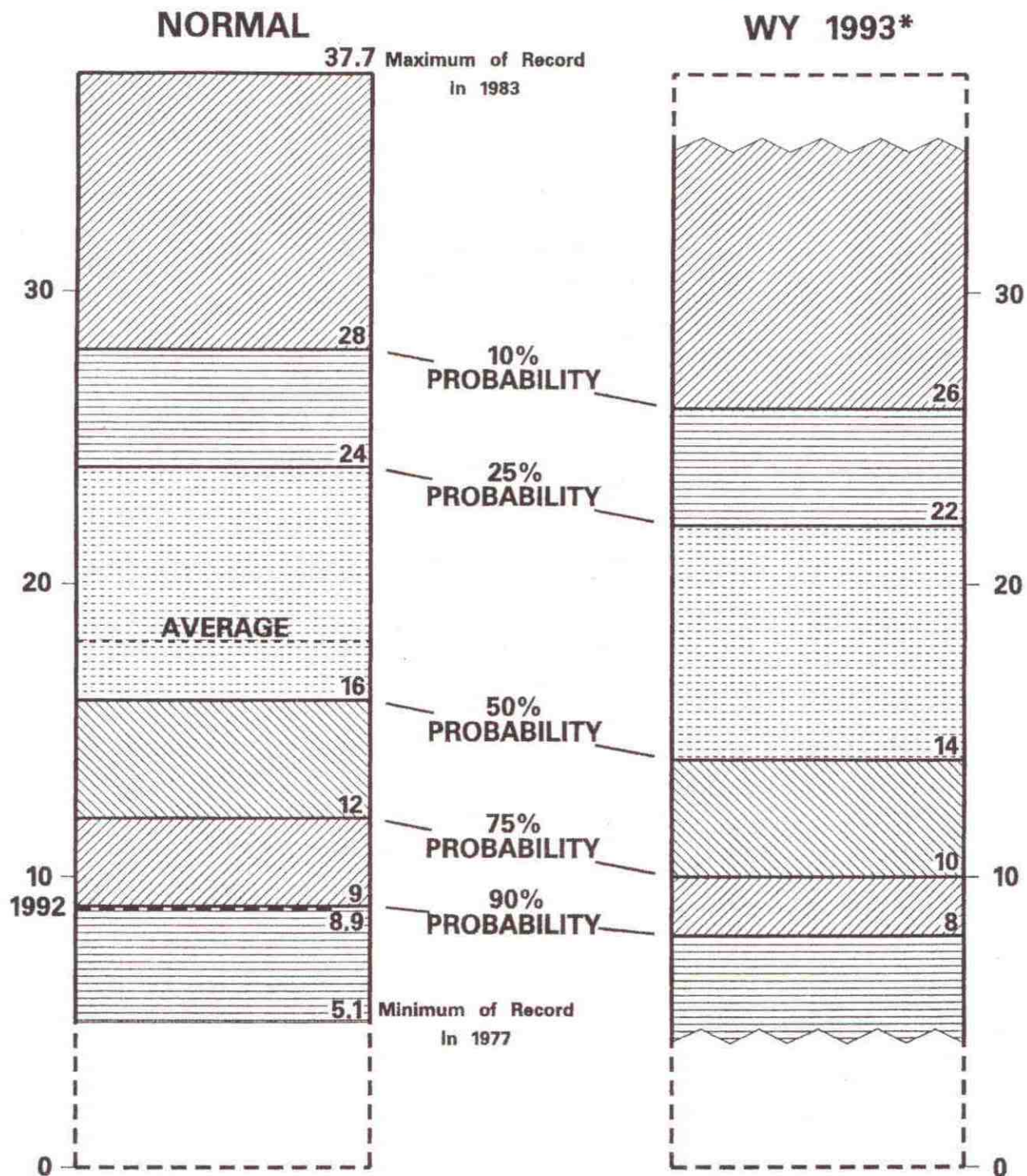


NOTE: The Sacramento River Index is the sum of unimpaired runoff from the Sacramento River at Bend Bridge, Feather River inflow to Oroville, Yuba River at Smartville and American River inflow to Folsom.

# WATER YEAR RUNOFF PROBABILITIES

## Sacramento River Index

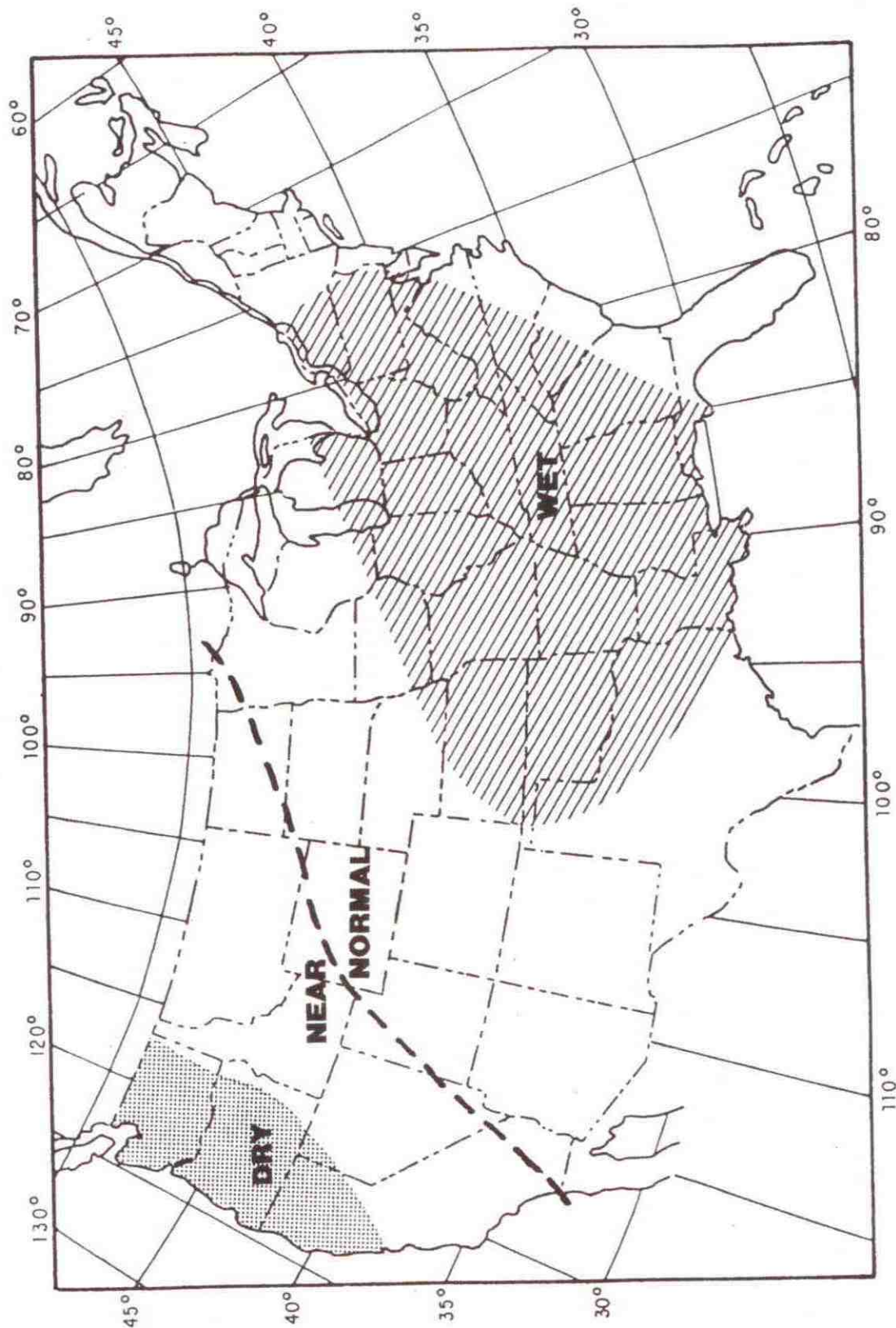
AMOUNT IN MILLION ACRE-FEET



\* AS OF OCTOBER 1, 1992

# NATIONAL WEATHER SERVICE PRECIPITATION FORECAST

October through December 1992



ISSUED SEPTEMBER 29, 1992